SAVE IT

No, this is not a government campaign, its an OUGS one. By now you will have realised that despite our steep rise in fees the OUGS still offers by far the best value for money of any of the OU societies. It is a pity that we are now having to help towards the cost of printing the Journal and Newsletter (and I choose my words carefully). Have no doubts about it, you are still being subsidised by the OU, and not only in terms of the time people at Walton Hall give to the OUGS.

I'm sorry that cash flow problems meant we had to drop the early issue this year, so depriving those dropping their membership of a final reminder of just what they will be missing. However, I'll see that those of you who have rejoined get as many 'goodies' during the year, which you all deserve after the excellent response to our request that you rejoin promptly. By the end of January we had £700+ in the kitty, against £57 last year! As Keith explained in the delayed Christmas issue of the Newsletter, the Journal and Newsletter cost us about £900 last year, so we've almost covered that quarter of the year's expenses. Incidently, if we were to try to get over the delays occasioned by our piggybacking on the OU services we would have to find another £1100 (or 160 members) a year.

So we come to the Save It Journal. We have explored many ways of cutting our costs, which amount to almost £5 per page. Firstly we have a new format – well three actually. To get more words on to a page we are using a slightly smaller typesize and a slightly larger printed area. As you can see on this page, doing this across the full measure, whilst it allows us to get a lot more on the page, does not give a very readable result, so we will only use this style on things like the editorial and letter pages. For the four articles we've managed to squeeze into this issue we move to a new two column format, which I hope you will find easier on the eyes. For Branch Reports we're trying another tack suggested by our illustrator, Anne Bennett. Anne suggested we reduce our existing layout and typeface by 75% and put two pages on each side of the sheet. It takes a bit of getting used to, and I'd welcome your comments as to whether you think that it works well enough to be carried on next year, or whether you would rather go back to the old style and pay the extra.

Our second innovation is *paid* advertising, when we can get it. As each advert pays enough to have two pages of the Journal printed the more the merrier – any takers? Finally we've put some restrictions on Branch Reports. Unfortunatley we must now cut all reports to 2000 words and drop any associated diagrams, etc. I'd also like to clear up a misunderstanding – Branch Reports have *never* qualified for free membership, they are a labour of love. What does qualify are articles, projects and field guides that can be followed by unaccompanied individuals. Incidentally, the free membership is for the year *after* the date of publication – it's worth more that way – and long letters don't count. Having said that, who wants to earn £7+ for an article?

Three of our four articles this time are based on OU projects, though only Elinor Broadbent's paper is close to the original form submitted to the OU. It makes interesting reading and shows how a competent project should be presented. Well done Elinor. My thanks also to Denis Jackson for reviewing Pat Jilks' paper – sorry I didn't have space to include the acknowledgement with the paper Denis!

The new layout doesn't allow us so many fillers, but the few there are this time come from the real *Devil's Dictionary*, published in 1906 and now released by Dover Publications via Constables for a mere 95p – about the best value for money in the book trade these days. As you can see the master makes our efforts look puny, but surely someone can help me follow that.

Martin Bryan

THE INACCESSIBLE EARTH

Geoff Brown and Alan Mussett

This unique treatment of the interior of the Earth is, perhaps, the first easily readable, in-depth book based on insights from the wide range of disciplines, from geology to nuclear physics, that address this fundamentally important topic.

Why do we think that the centre of the Earth is a nickel-iron alloy; or that the crust grows by new additions at subduction zones; or that the Earth's magnetic field is generated by some form of convection in the molten outer core? Our present understanding of the Earth's interior comes from many disciplines, but until now there has been no synthesis aimed specifically at undergraduates and teachers in the Earth Sciences. The aim of this book is to achieve a new blend of evidence about the origin, evolution and present nature of the Earth, without being too advanced or highly mathematical.

The book traces the establishment of the Earth's layered structure and density from seismic and gravitational data, and proceeds to discuss the origin and abundance of its constituent elements by reference to theories of stellar and planetary accretion, and to the evidence from solar spectra and meteorites. With this information as background, the second half of the text is aimed specifically at describing the probable composition and state of the present-day core, mantle and crust. Such contemporary processes as mantle convection and plate tectonics are also discussed in terms of their driving forces and evolution.

Fully illustrated and with comprehensive bibliographic references, this book provides an attractive and comprehensible account of a truly fundamental topic in the Earth Sciences.

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THE GROWTH AND DEVELOPMENT OF THE RELATIVE PHANEROZOIC TIMESCALE

Richard Wilding BA (Open)

Introduction

> "Go my Sons, buy stout shoes, climb the mountains, search the valleys, the deserts, the sea shores, and the deep recesses of the earth. Look for the various kinds of minerals, note their characters and mark their origin. Lastly, buy coal, build furnaces, observe and experiment without ceasing, for in this way and in no other will you arrive at a knowledge of the nature and properties of things."
>
> *Severinus 1571*

Geological observation has had a long history. Before Severinus that great scientist and artist Leonardo da Vinci, in his notebooks, had produced reasoned arguments for the organic origin of fossils, given accurate accounts of the formation of littoral deposits and explained how casts and impressions of plants and animals were produced in rocks.

The collection of basic geological data took a long time to get underway. It is probable that too rigid an interpretation of the Biblical accounts of creation helped to inhibit for many centuries the establishment of a sufficiently scientific approach to Earth history. Geology largely differs from other sciences in that it is concerned with the past development of the natural world, and only the end products of past processes are revealed by observation. Experimental results can only be applied by analogy. So earlier centuries were full of wild guesses and imaginative speculation. These had to be replaced by some recognisably valid principles before geology could begin to move forward as a science. This needed a major reappraisal

This 'Geological Revolution' received its impetus from the Industrial Revolution, and was part of what historians have called the Age of Revolutions. The industrialisation process threw into prominence the need to find, utilise and, therefore, to fully understand those resources that a growing and changing economy required in increasing amounts. Mining had been practised for centuries and a certain quantity of local knowledge of rock relationships was available, but towards the end of the eighteenth century a real economic need arose for something more than purely descriptive groupings.

The Early Development of Stratigraphy

Early Attempts at Division

In 1669 Niels Stensen, a Dane also known as Steno, published the first formulation of the principle of superposition, an almost self-evident principle which states that in any sequence of horizontal or near horizontal strata the lowest beds are oldest. He recognised that strata are often tilted or deformed by earth movements. Later, criteria were established by which the tops and bottoms of beds in deformed and deeply tilted strata could be recognised.

This basic principle enabled geologists to attempt some sort of division of the rocks of the Earth's crust. Initially, in the seventeenth and eighteenth centuries, these were merely local and regional descriptions of stratal successions, such as John Stracey's 1719 section through the coal beds and overlying strata south of Bristol. Later some attempts were made at weaving together the

whole history of the Earth. Many were descriptive generalisations; others led to faulty hypotheses. Facts were in short supply, so speculation flourished. This was the age of the 'system builders', described by Buffon in his *Histoire Naturelle* as showing "the tendency of man ... to find regularity where variety reigns".

For instance, two Germans, J. G. Lehmann (1756) and G. C. Fuschel (1762), both drew up schemes of successive strata that they considered were due to the action of different physical agents in successive epochs, and Giovanni Arduino (1713-1795), an Italian, divided the whole succession of stratified rocks into three classes, which he designated the Primitive, the Secondary and the Tertiary. The last, of course, is a designation that still survives in our present day geological timescale.

Of greater influence in his day was Abraham Gottlob Werner (1749-1817), who largely dominated geologic thought at the end of the eighteenth century and did more than any other to raise geology to a science. His work on minerals was of great importance. Unfortunately he is chiefly remembered for his false assumption that the whole Earth was once covered by an ocean in which most rocks were formed, mainly by chemical precipitation. His system recognised five main phases:

1 Primitive rocks (granite, gneiss, porphyry, etc), the first to crystallise in the primeval ocean
2 Transition rocks - some precipitated chemically (slates and shales) and some mechanically (greywackes)
3 'Flotz' or secondary rocks (limestones, sandstones, chalk, basalts) built up of fine particles torn from the slopes by receding torrents
4 'Alluvial', 'derivative' or 'transported' strata (clays, sand, pebbles)
5 Volcanic rocks, of which there were two subdivisions: a) true volcanic rocks (lava, ejectamenta, pumice, tufa, etc) from late, post-aqueous volcanoes, activated by the ignition of coal deposits; b) pseudo-volcanic rocks (burnt clay, 'porcelain jasper', hornstone, etc).

A large number of objections could be raised against Werner's system, for it was contradicted by numerous observable facts. It says a great deal for his great teaching abilities that he was able to impress these views on a large number of people.

By the end of the eighteenth century, and well into the nineteenth, the terms Primitive, Transition, Secondary and Tertiary were the most commonly used, and these had much the same significance that we today attach to the Eras.

James Hutton

So far geological time had hardly entered the picture. The Wernerian system, for instance, could be considered as taking either a very long or a very short time, according to individual views on the antiquity of the Earth. Nor had any important stratigraphic principles been added to Steno's basic 'law of superposition'.

In 1788 a great stride forward was made with the publication of the first volume of *Theory of the Earth* by James Hutton, a Scot. (An abstract had previously been published in 1783.) A second volume was published in 1795, and a third volume was rescued from manuscript by F. D. Adams and Archibald Geikie and published as late as 1899.

In these books several new and important principles were established. Most important of these was Hutton's insistence on the great length of time over which geological processes take place - "we can see no vestige of a beginning, no prospect of an end". It also established the 'principle of uniformity', by which past processes can be explained in terms of those which can be seen to be currently in operation.

An important part of Hutton's theory was that basaltic and granitic rocks were of igneous rather than aqueous origin. By showing the intrusive nature of granites, and by giving accounts of concordant and discordant minor intrusions, he established the importance of the time relationships of these to stratigraphy.

The 'vulcanist' versus 'neptunist' disputes of this period, in which the two factions tended to align themselves either with Hutton or with Werner,

were, in fact, older than either of these men. As Professor R. H. Dott has pointed out: "Much more profound was the little appreciated neptunian implication of a structurally static solid Earth versus the plutonian assumption of a continuously dynamic one."

Although Hutton placed too great an emphasis on the Earth's internal heat, which he wrongly supposed was the means of consolidation of strata, his uniformitarian views ultimately prevailed and he is rightly regarded as the 'Father of Geology'. Yet the names of two other men are linked with his achievement.

The first of these, Sir James Hall (1761-1832), demonstrated the correctness of the Huttonian view that basalt is of igneous origin by melting some specimens. He first obtained a glass by allowing the melt to cool rapidly, and later obtained a recrystallised basalt by slower cooling. Hall's experiments, which also included the demonstration of a metamorphic change (obtaining marble by heating powdered limestone in sealed porcelain tubes), mark the beginning of laboratory investigations of geological processes.

Secondly, Hutton's theory owes a great deal to John Playfair (1748-1819), who published *Illustrations on the Huttonian Theory of the Earth* in 1802 (Hutton had died in 1797). This was a masterpiece of geological literature which both clarified Hutton's writings and adduced many additional 'illustrations and observations'. Archibald Geikie, who himself produced geological literature on great themes, was to comment in 1905: "How different would geological literature be today if men had tried to think and write like Playfair".

The Development of Palaeontology

William Smith

In his *Discourses on Earthquakes*, written between 1686 and 1689 and posthumously published in 1705, Robert Hooke made a number of original suggestions from his studies of fossils: on variation and progression due to changed conditions; that climatic changes could be inferred from fossils; on the extinction of species; and - most importantly here - that it might be possible to use fossils as a chronological index. It was largely due to the chaotic state of geological science that these ideas were not developed earlier. It was not until about a century after Hooke that a poorly educated surveyor and engineer, William Smith (1769-1839), deduced the principle of faunal succession which was later to lead others to use specific fossil aggregates to delineate units in a timescale.

Smith's work as a canal engineer led him to observe strata. He came to realise that each stratum could be recognised by the fossils found in it, and that it was possible to correlate strata over large areas by means of their fossil contents. In 1799 he drew up a table of *British Strata from the Coal Measures to the Chalk*, which had a limited distribution in manuscript. From this time he devoted his life's work to producing the first coloured geological map of England and Wales.

He impoverished himself in the process, but the map, with an accompanying memoir, was finally published in 1815. This demonstrated the principle of faunal succession, and also its practical applications. His introduction to the memoir is largely an exposition of the practical benefits to mining, farming, canal building, road building and other industries. As he put it: "There are few arts or employments which have not derived some useful hint or improvement from a better knowledge of our soil and substrata."

It is interesting to note that at this period the professional geologist hardly existed; for most of those who pursued the science were members of the leisured classes. Smith observed that: "The theory of geology was in the possession of one class of men, the practice in another." Yet this modest, self-effacing man was eventually recognised by contemporaries of all classes as having made one of the most significant contributions to the growth of the young science of geology.

Catastrophism versus Uniformitarianism

Baron George Cuvier was born in 1769, the same year as William Smith, and was certainly a mem-

ber of the leisured classes. His major work was the application of the principles of comparative anatomy to an elucidation of the remains of fossil vertebrates. J. B. Lamarck (1744-1829) did much the same thing for the invertebrates. But although Lamarck believed in a theory of descent with modifications, and developed an evolutionary theory based on the inheritance of acquired characteristics, Cuvier believed in the fixity of the species. He postulated, in his *Essay on the Theory of the Earth* (1817), that several great changes had been produced on the surface of the Earth by great catastrophes, which were sudden in occurrence and killed off one set of creatures, after which a new set was created. These account for changes in flora and fauna in the fossil record, the last of them being the biblical Noah's Flood. His ideas found ready acceptance among the naturalists and geologists of his day, so Cuvier is regarded as both the 'Father of Palaeontology' and also as the 'Father of Catastrophist Geology'.

It must not be forgotten that catastrophist geolgists contributed a great deal to geological sciences. It may be difficult for us nowadays to put ourselves into the religious and cultural climate in which, for instance, the Rev. Joseph Townsend, a geologist who was both a pupil of William Smith and one of those who encouraged him to write down and publish his findings, could write a geological work with the title *The Character of Moses Established for Veracity as an Historian, Recording Events from the Creation to the Deluge* (1813). Yet Townsend was an honest geological observer whose work is of some importance in the history of geology, even though we now know that some of his conclusions were erroneous.

The catastrophists' objection to uniformitarianism particularly the later Lyellian version of it, was the perfectly valid scientific one that it was an hypothesis that could not be proved. When, later, largely as a result of the work of Jean Louis Rodolphe Aggasiz (1807-1873), the founder of glacial geology, the evidence for Ice Ages began to accumulate, the catastrophist geologists were generally more receptive to the idea than the strict uniformitarians.

Charles Lyell (1795-1875), in his *Principles of Geology* (1830-3), founded strict uniformitarianism. His system postulated that the same physical laws have always worked in the same system of interactions, through the same physical agencies and with the same quantities and intensities as at present. It is important to distinguish this from Hutton's kind of uniformitarianism. As Dott has pointed out: "Hutton's statements that 'we are not to limit nature with the uniformity of an equable progression' and that distinctiveness of the Primary, Secondary and Tertiary 'are in reality nothing but the variable measure of similar operations' indicated that he was closer to actualism than strict uniformitarianism."

Dott also pointed out another aspect of Lyell's conception that is worth quoting fairly fully:

> "A wholly cyclic view of the Earth is illogical, yet ever since Hutton geologists have sought cycles in nature (climatic, erosional, orogenic and especially sedimentary ones). They seem to have been eminently successful, but unfortunately many supposed cycles are fabrications. The cyclist zeal should be dampened by a reading of Zeller's experiment in the fabrication of a supposed repetitive stratigraphic pattern using the Lawrence, Kansas, telephone directory as a random numbers table. Many cycles in the geological literature clearly represent an imposing of order on nature by man. The error is a subtle assumption of perfect transcendent cyclicity that is a complete return to the previous configuration as in a sine curve - a kind of *cyclic uniformitarianism*. Long ago Lord Kelvin regarded such a view of geological history as erroneous, and so launched his half-century vendetta with geology. He was basically correct in attacking the popular nineteenth century Lyellian concept of uniformitarianism as amounting to perpetual motion - a physical absurdity. Lyell's view, which allowed only oscillations within strict limits, amounted to a *steady state* Earth; ... Hutton perceived what we today may term *dynamic equilibrium*."

Lyell tended to regard the methodological principle of uniformitarianism as if it were an invariable scientific 'law', which it is not. In his system cumulative developments were considered impossible, and even the possibility of progressive organic change was refuted. To him palaeontology showed no evidence of fundamental change or progression in fossil forms. He did, however, to some extent modify his original extreme views. He continuously revised the *Principles* through eleven editions (the last in 1872) as field work progressed and geology developed.

As for Cuvier, although his kind of catastrophism is no longer accepted and we know, for instance, that the 'evidence' for Noah's Flood was later interpreted as glacial deposits, catastrophism is by no means a dead issue, even today. For example, what if not 'catastrophist' is the fairly recent hypothesis that sudden extinctions of successful species such as the dinosaurs may have been caused by a sudden increase in solar radiation if the strength of the Earth's magnetic field died to zero at times of polarity reversals? Is not the creation and later break-up of the super-continents Laurasia, Gondwanaland and Pangaea also essentially 'catastrophist' when the events are considered in relation to their effect on evolutionary change? The term 'neo-catastrophism' has been used to describe some aspects of modern geology.

It is perhaps better to view the present consensus as descriptive of an 'evolutionary dynamic Earth'. This, to some extent, combines something of both catastrophism and uniformitarianism, as well as adding an extra dimension to the picture that is not unimportant when considering the Earth's journey through time.

Subdividing Geological Time

The Major Subdivisions of the Geological Timescale

The subdividing of the geological timescale into its major divisions, and also the more precise defining and usage of time/stratigraphic terms, did not happen at once. It was a piecemeal affair in which a large number of geologists were involved, either directly or indirectly, and which took the better part of a century to accomplish. The following is no more than a brief summary of how the Periods and Eras came to be named and defined.

The Periods

In 1822 W. D. Conybeare and W. Phillips published their *Outlines of the Geology of England and Wales*, which summarised existing knowledge. In it they discussed the Carboniferous order, recognising four subdivisions: Coal Measures, Millstone Grit, Carboniferous Limestone and Old Red Sandstone (the latter group was later included in the Devonian).

In the same year, in France, d'Omalius d'Halloy mapped and named the Terrain Cretacé or Cretaceous system. In this he included not only the Chalk but also the Greensand, Ironsand and Marl beneath it. In the 1830s two other French geologists, O. Dufrenoy and J. Elie de Beaumont, clarified the Cretaceous sequence by noting that it had two basic subdivisions, a Lower Group including the Wealden Beds, the Neocomian beds newly recognised in the Juras, the Greensand and the Marls, and an Upper Group, which was the Chalk.

In 1829 Paul G. Desnoyers classified certain deposits in the Seine basin which he thought to be younger than Tertiary rocks as Quaternary. As it has since turned out, these may not, in fact, have been Quaternary deposits. Today the period is divided into the Pleistocene Series (a term proposed by Lyell in 1839) and the Recent Series (proposed by Lyell in 1833).

In 1834 Friedrich August von Alberti, an official of the German salt mining industry, recognised that a sequence of rocks with a striking three-fold division - the Bunter Sandstone, the Muschelkalk Limestone and the Keuper Marls and Clays - together contain a sufficiently individual aggregate of fossils that they could be grouped together as a single unit, and that these fossils were "the thermometer of a geological period". He provisionally named the unit Trias - hence Triassic.

The Transition beds, or 'old greywackes', beneath the then Secondary rocks were essentially an uninvestigated puzzle until, in the 1830s, Roderick Murchison and Adam Sedgwick of the Geological Society of London set out to unravel this complex sequence. Sedgwick worked in northwest Wales from the base of the sequence. Murchison began in southwest Wales and the border counties, working down from the top. Murchison used fossils to correlate his strata, but Sedgwick's strata were poorly fossiliferous, so he worked mainly on the lithologies. In 1835 they both published the results of their labours. Sedgwick named his rocks the Cambrian (from the old name for Wales) and Murchison used the designation Silurian (from the name of an old Welsh tribe) for the sequence he had investigated. At the time it was thought that Sedgwick's Cambrian strata plunged under Murchison's Silurian. Only later did it become apparent that there was an area of overlap between the two sequences. This led to a quarrel between the two friends and a difficulty that took some years to resolve.

Before the split between them, Murchison and Sedgwick also jointly investigated and named the Devonian system, in 1839, from the slates, sandstones and limestones lying beneath the Carboniferous beds. They also showed that the fossils could be used to recognise and correlate the Devonian rocks of the Rhineland with those of the type area. The Old Red Sandstone was an important part of the Devonian sequence.

Alexandre von Humboldt, a pupil of Werner, used the term 'Jura-Kalkstein' to describe a massive limestone formation in the Jura mountains in 1799. He considered this an important formation, but it was only part of what was later known as the Jurassic strata. Conybeare and Phillips recognised an Oolite Series with two formations, the Oolite (above) and the Lias (below). In this they followed William Smith, who also described these stratal units and their fossils. But the Jurassic was first described as a system in its own right by a German, Leopold von Buch, in 1839. He divided the German equivalents of the British series into three units: Upper or White Jura, Middle or Brown Jura and Lower or Black Jura.

In 1840 and 1841 Roderick Murchison paid two visits to Russia with the French palaeontologist Edouard de Verneuil. On the second visit, with the blessing of the Czar and the help of Russian geologists, he examined strata and collected fossils from east of Moscow to the Urals, a five-month trip that resulted in the establishing of a new period. In a letter to the Russian Academy of Science at Moscow he proposed the name Permian, after the small town of Perm, west of the Urals. He also established the name in an article published on his return to England.

In 1879 Charles Lapworth finally settled the problem that arose from the area of overlap between Sedgwick's Cambrian and Murchison's Silurian. He noted that these rocks contain three distinctive faunas and proposed that the two systems be redefined. He suggested that the "strata included between the base of the Lower Llandovery formation and that of the Lower Arenig" be known as the Ordovician, after the last of the old British tribes to yield to the Romans, the Ordovices. This suggestion was slow in gaining favour. As late as 1903, in the fourth edition of his *Textbook of Geology*, Archibald Geikie stoutly defended Murchison's earlier definition of the Silurian. He stated: "I shall continue to employ Murchison's terminology, which has the claim of priority, and in my opinion is perfectly sufficient for the requirements of science." Even today the position of the Cambrian/Ordovician boundary is not internationally agreed.

The Eras

The terms Primitive, Transition, Secondary and Tertiary were originally applied to large descriptive rock units. As the periods developed into time-interpretive units a need was recognised for interpretive units of greater magnitude. As time-interpretation was based on fossil aggregates, geologists observed that beneath the fossiliferous strata there was a large unit that contained few fossils. This is the Precambrian, which is outside the range of this paper.

In 1838 Adam Sedgwick proposed the term 'Palaeozoic Series' for what is now known as the

Palaeozoic Era. In 1840 John Phillips first used the terms 'Mesozoic Era' and 'Kainozoic Era', and in 1841 he elaborated on his original article and made it clear that the Eras should be interpretive divisions "... we resolve to employ the characters supplied by successive combinations of organic life ...".

Lyell's Percentages

The great work of Charles Lyell was indubitably his division of the Tertiary and Quaternary. In the third volume of his *Principles of Geology* he compared numbers of still-living species of marine molluscs at various stratigraphic positions with the number of extinct species. On the percentage of the former he subdivided the Tertiary rocks into:

Recent - rock layers from the period when the Earth was first inhabited by man
Newer Pliocene - rocks with approximately 90% of their fossils represented in living species
Older Pliocene - rocks with between 33% and 50% of their fossils represented in living species
Miocene - rocks with approximately 18% of their fossils represented in living species
Eocene - rocks with approximately 3½% of their fossils represented in living species.

In 1839 he amended his original terminology and restricted the term Pliocene to what he had earlier called Older Pliocene. He gave the term Pleistocene to what earlier was Newer Pliocene. A few years later, in 1846, Edward Forbes noted that the glacial epoch was synonymous with the Pleistocene. In 1856 the Recent and Pleistocene series were recognised by C. A. von Morlot as part of the Quaternary.

Lyell's Tertiary sub-units, which he originally termed 'periods', are today known as 'epochs' (Lyell used both terms as practically interchangeable descriptions). Lyell also predicted further subdivisions of the Tertiary, and in 1854 Heinrich Ernst von Beyrich applied the name Oligocene to rocks which some geologists had begun to regard as Lower Miocene.

Similarly, in 1874, W. P. Schimper split off the lower part of Lyell's Eocene and founded the Paleocene Epoch. He did this, however, on floral aggregates rather than the percentage of still living marine molluscs used by Lyell. Lyell's method was certainly among the first to define units of the geological timescale based on interpretation of faunas, but it could only be applied to Tertiary deposits. Something else was needed to subdivide the earlier deposits.

D'Orbigny's Stages

In his work on the Jurassic strata Alcide d'Orbigny (1802-1857) noted that similarity of faunal assemblages was the key to the correlation of local rock units and their faunas. He saw that certain groups of strata were characterised by certain fossil assemblages or aggregates. Brushing aside lithology, he designated a group of strata bearing the same fossil assemblage 'a stage'. To d'Orbigny each of the faunas typifying one of the stages was the result of a creation following a catastrophe. He exaggerated the geographical extent of his stages, but this was a development of the work begun by William Smith. It was pointing in the right direction and further refinements were to follow.

D'Orbigny's catastrophist ideas were not, of course, acceptable to the strict uniformitarians, but his stages found quick acceptance from some geologists, who added other stages to those that he had already delineated. But precise stratigraphic work on the range of species, and increasing knowledge of their geographical distribution, was beginning to point the direction in which his ideas could be modified.

Oppel's Principle

The method by which all fossiliferous strata could be subdivided into small-magnitude units that were clearly and precisely delineated was eventually defined between 1856 and 1858 by Albert Oppel (1831-1865). He investigated and plotted

the vertical stratigraphic distribution of a large number of species at many different places. Like d'Orbigny he ignored the lithology of the beds. He found that there were groups of strata bearing closely similar fossil aggregates, and noted that the stratigraphic range of species varied in length - some very short, some very long, but with most of intermediate length. He discovered that the distinctive faunal aggregates that certain groups of strata possesed were the results of the *overlapping stratigraphic range of species*.

Oppel found that he could mark the boundaries between the distinctive aggregates by using the appearance of new species. Thus he could distinguish between successions of aggregates, each of which was bounded at its base by the appearance of certain new species. He called these diagnostic aggregates 'zones'. As the appearances of new species are unique events in time, no previous principle had led to such definite time intervals. Oppel further grouped zones into stages which were characterised by larger magnitude fossil aggregates. His stages were, however, slightly different from d'Orbigny's.

Not long after Oppel's work Charles Darwin published *On the Origin of Species* (1859). This contributed evolution through natural selection, and helped to explain why the vertical range of fossil species overlap. Also, in Oppel's system, it is quite usual for a species to range through two or more zones; this, and the varying range of species, was also explained by Darwin's hypothesis.

Oppel's principle is still used today. We sometimes use the term 'concurrent range zones' to describe zones based on overlapping ranges. It has been improved upon and refined, but basically no one has yet come up with any better method for the precise and reliable marking of a time/stratigraphic zone. Lithofacies maps and isopach diagrams have their greatest meaning when they are constructed for particular zones.

It has also been recognised that time/stratigraphic zones have definite geographic limits. The term 'biogeographic province' is used to describe an area outside of which a concurrent range zone cannot be recognised. It is possible, however, to correlate groups of zones or stages over adjacent provinces, or even on a worldwide basis in some instances.

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Editor's Note

My thanks to Mavis Fewtrell of the OU for refereeing this paper. Ambrose Bierce's definition of geology in the original *Devil's Dictionary* (1881-1906) shows how influential some of the older terms are!

Geology, *n.* The science of the earth's crust – to which, doubtless, will be added that of its interior whenever a man shall come up garrulous out of a well. The geological formations of the globe already noted are catalogued thus: The Primary, or lower one, consists of rocks, the bones of mired mules, gas-pipes, miners' tools, antique statues minus the nose, Spanish doubloons and ancestors. The Secondary is largely made up of red worms and moles. The Tertiary comprises railway tracks, patent pavements, grass, snakes, mouldy boots, beer bottles, tomato cans, intoxicated citizens, garbage, anarchists, snap-dogs and fools.

Have you seen any garrulous men, fools or intoxicated citizens on your field trips?

GEOLOGICAL CONTROL OF THE DISTRIBUTION OF PLANTS

Elinor Broadbent

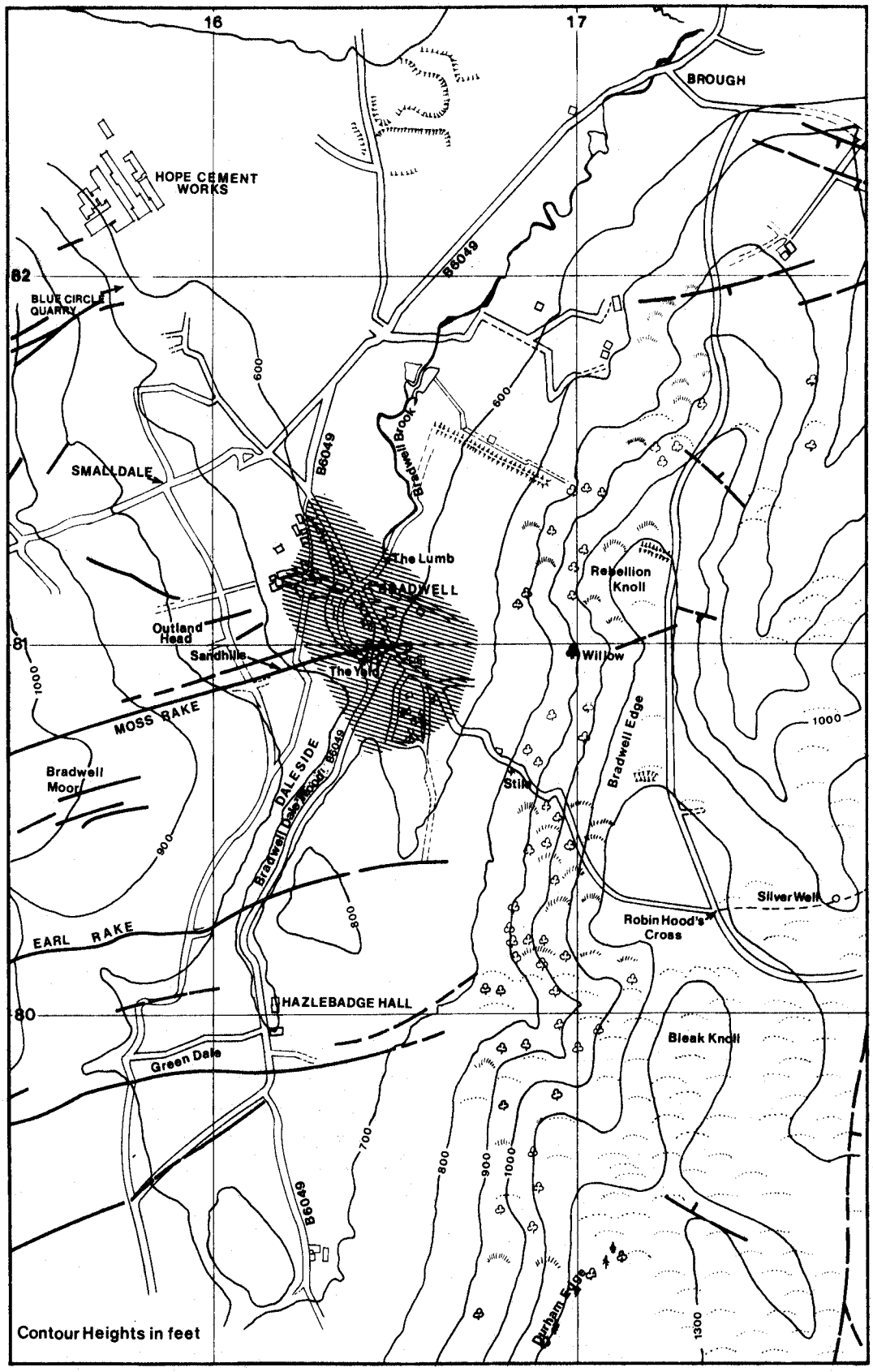
Introduction

This project was undertaken with a view to discovering any geological control in the distribution of plants in the areas adjacent to the village of Bradwell, in the Peak District of Derbyshire, where I live. The areas concerned include Bradwell Dale, Bradwell Edge, Bradwell Moor (over which a line of mineral rakes, disused lead mines and flourspar workings run) and the Bradwell Brook, which issues from the underground Bagshawe Cavern and flows through the village to join the River Noe, a tributary of the Derwent, at Brough.

The geology of the surrounding area is of considerable interest and complexity. The Derbyshire 'Dome' has a core of limestone surrounded by the sandstones and shales of the Millstone Grit, which in turn are flanked by Coal Measures to the east and west and, finally, by Permo-Triassic rocks. The core of the Dome is a limestone massif, flanked by outward-dipping reef limestones, which was laid down in the Carboniferous era. Bradwell, a typical Derbyshire village, is situated at the northern end of the Bradwell Dale, which lies along the northeast boundary of the Carboniferous Limestone outcrop. The Dale itself, less than a kilometre in length, is a deeply incised gorge without a stream - an excellent example of a dry valley. The B6049 road runs through it, southwards to Tideswell, and is bounded on either side by towering cliffs of thickly-bedded pale grey limestone, modified (on the right) by quarrying operations earlier this century and (in the grassed-over area nearer the village) in more remote times. The Elizabethan manor house, Hazlebadge Hall, stands at the southern end of the Dale, and north of it runs a sphalerite-bearing mineral vein, the Earl Rake, with its ENE-WSW direction. The Bradwell Dale cave system is much smaller than that at Castleton, but it does contain one major resurgence cave, the Bagshawe Cavern, and it is from thence that the Bradwell Brook emerges in The Lumb in the village.

This stream responds strongly to precipitation - a base flow of 3mgd can increase to 35mgd. There are four known sinks for the Bradwell hydrological system, three of which have been proven by dye testing and the fourth inferred. Edmonds (1971) analysed three Bradwell waters, and the results showed it to be fairly typical Derbyshire karst water. In addition to the contibutory run-off from the Millstone Grit on Bradwell Edge, a small thermal spring discharges behind the Thatchers Inn (formerly the Bath Hotel) with a temperature of 124°C. It has twice the hardness of the other springs, and its origins have been attributed to the (known) presence of volcanic rocks beneath the Blue Circle Quarry - the reaction of the oxidation of pyrite on deep phreatic drainage.

The high ground to the east of Bradwell Dale extends to Hucklow Edge southwards and Eyam Edge eastwards, and is composed of Namurian strata lying, probably unconformably, upon the limestones. The Edale Shales, of variable thickness, at the base are succeeded by the Mam Tor Beds and the Shale Grit. The Edges are capped by sandstones from the Millstone Grit. Geological Survey Sheet SK18 (Edale and Castleton) covers the detailed geology of the area. Before the advent of the Derwent Valley Water Scheme the inhabitants of the village depended for their water supply on a small reservoir situated halfway up Bradwell Edge.


16
17
BROUGH
HOPE CEMENT WORKS
82
BLUE CIRCLE QUARRY
B6049
600
SMALLDALE
Bradwell Brook
The Lumb
BRADWELL
Rebellion Knoll
Outland Head
Sandhills
81
1000
The Yeld
Willow
MOSS RAKE
Bradwell Edge
Bradwell Moor
DALESIDE
Bradwell Dale Head
Still
900
800
Silver Well
Robin Hood's Cross
EARL RAKE
HAZLEBADGE HALL
80
Bleak Knoll
Green Dale
700
Durham Edge
1300
Contour Heights in feet

Bradwell Moor rises to the west of Bradwell Dale. It is a dip slope some two kilometres long, topped by a plateau at about 1300-1400 a.o.d. The limestone beds here are in the D^2 zone, and they dip slightly more than the average slope. The beds higher stratigraphically outcrop lower down the slope (eg in the Yeld in the Dale). Most of the D^2 zone is composed of regularly-bedded cherty limestone of the Monsal Dale series, overlain by limestone of the Eyam series. Outland Head has had a limestone quarry since 1898, and in recent years it has been extended by Hoveringham Gravels. The Bradwell Spar Mining Co. worked the old lead mines in the area known locally as 'The Sandhills', extracting flourspar, in recent years, and is still engaged in this activity on Moss Rake and at the top of Smalldale.

Hypothesis

In an area of such geological diversity one might reasonably expect considerable variation in the distribution of plants, and this is what I set out to prove or disprove.

Methods

On walks to and from the village shopping every day, at weekends and in the longer summer evenings I was able to observe and list the vegetation – trees, shrubs and flowers. I followed the course of the Bradwell Brook some distance. In fine weather I climbed the Bradwell Edge, and walked across the top from Robin Hood's Cross to Rebellion Knoll. From there I descended diagonally to the old bridle path. I went further afield on Bradwell Moor, collecting more botanical data, visiting Moss Rake (well known to OU students for its superb mineralisation!). I also took a number of soil samples at selected points in the different areas and tested them for pH, lime, nitrogen, phosphorous and potash using the Sudbury Soil Test Kit (on sale at Boots).

Discussion

Bradwell Edge faces west. The lower slopes are well wooded - mostly hawthorn, but mountain ash and holly are also represented. Towards the top the hawthorn bushes become very stunted, and are generally replaced by gorse, heather and bilberrires. Instead of the ubiquitous limestone walls one finds across the valley the stone walls and stiles here are constructed of Millstone Grit. Cattle are (and apparently always have been) pastured on the Edge, and seem to do well on it. There were some patches of bracken, but not much, and it was very stunted towards the top. Foxgloves were plentiful and, along with gorse and bilberries, confined to this area. Mountain pansies grew close to the summit. There are springs in the Edge, and it can be damp underfoot at times in certain places, but it was a surprise to find a huge willow tree, with a girth of about eight feet, three-quarters of the way down the Edge. The soils are brown acidic earths, but one sample from the lower slopes was a rather damp clay.

The Daleside is also well wooded, hawthorn and elderberry being the principle tree cover. Brambles and elderberry bushes flourish here. Hawthorn and sycamore also grow very well. After the Second World War poultry were kept on part of the Daleside and, later, some pedigree goats browsed over it, but there has not been any livestock on it during the past decade. In the upper part primroses, bluebells, wood sanicle and forget-me-nots flourish. White arabis grows on the rocky outcrops. The rare yellow toad flax grows in one special place. Wild thyme is fairly widespread and inclined to form a dense carpet, so excluding other flowers, the dry banks on the Daleside being a typical habitat. Cuckoo pint is found in the shelter of the elder trees in the little wood in the Dale. Nettles and rose bay grow intermingled nearer the bottom of the field.

The extensive rock and tree cover in the eastward sloping Dale furnishes more shelter and warmth for vegetation than either the Edge or Bradwell Moor. The soil in the Daleside is a dark brown loam with much organic matter in it. There appears to be intense insect life, with bees and butterflies being especially plentiful.

In the upland area of Bradwell Moor - the 'Sandhills' and Moss Rake - tree cover is virtually absent, so the vegetation is far more exposed to

high winds and storms. Conversely the vegetation here should receive the maximum of light and sunshine. Wild roses grow profusely over most of the old lead mine shafts. There is a very rich flora – harebells, orchids, seabious, bladder campion, yarrow, horsetail and birdsfoot trefoil being typical examples. It is possible to find some brambles and rose bay here also, but neither plant flourishes as well as its counterpart in the Daleside. The 'Sandhills' was extensively turned over by the spar miners in the 1960s, but there has not been any further mining since. It is too dangerous to pasture livestock here on account of the old mineshafts, but coltsfoot and horsetail have quickly colonised the bare patches on the spoil heaps. Strong anchorage is important, the coltsfoot having a creeping rootstock and the horsetail having creeping underground rhizomes. The birdsfoot trefoil flourishes early in the season, avoiding competition with the later blooming harebells and scabious. It also is firmly anchored in the sandy soil, with leaves growing in close rosette form. A red streak often marks the back petal, serving as a nectar guide to the bees that effect pollination. Bees, butterflies and moths are the common insects of the 'Sandhills' and red clover is another important bee flower with abundant nectar found in the area.

Cowslips appear to have found a congenial habitat in the little field across the way from Moss Rake. On Moss Rake itself the vegetation was similar to that in the 'Sandhills', except for the addition of some sloethorn.

The brook leading north from Bradwell has its own range of flora. At one point there is a landslip near the eastern bank, the area around apparently having sunk due to movement of the shale strata at the foot of the Edge. Willows grow on the bank opposite the slip, and monkey flowers and water crowfoot grow in the water in profusion, forming large, picturesque carpets. This, however, has the effect of blocking the stream, and does not find favour with the Parish Council. At present (1979) an experiment is being carried out to find chemicals capable of restricting the growth of these plants.

Results of the Survey

There proved to be quite a surprising homogenity in the vegetation of the three areas under consideration. The ubiquitous germander speedwell was in all three - literally everywhere. It is noticeable, however, that each area *did* have some plants not found in either of the others. There were gorse, foxgloves, bilberries and mountain pansies *only* on the Edge - the Millstone Grit area. Wild thyme, yellow toad flax, cuckoo pint and wood sanicle were exclusive to the Daleside - the sheltered limestone area - and horsetail, bladder campion and orchids are examples of plants found only on the 'Sandhills' - the exposed limestone upland area. The wild roses appeared to flourish much better in the 'Sandhills' area than elsewhere, but the rose bay and bramble did less well here than in the Daleside.

The soils sampled on Bradwell Edge were all acidic, with pH ranging from 4.5 to 5.25. The nitrogen test revealed a high humus content everywhere on the Edge, except near the entrance to the Dale where a slight drop was noted, though even then the value recorded was still quite high. The organic matter on the Edge must be decaying slowly, producing acids to make the soil minerals solvent and available to the plants. The phosphorous test revealed wide variations in phosphor content, from 2% near the entrance to the Edge and on the exposed summit near Rebellion Knoll to 8% at Robin's Hood Cross and near the willow on the lower slopes. As mentioned earlier, cattle have always been pastured on the Edge, and the manure no doubt contributes some enrichment to the soil. The soil test literature asserted that phosphorous acids were good for fibrous root formation, which helps plants to absorb food, including trace elements, from the soil. It was noticeable that the zone of heather, bilberries and gorse goes straight across the Edge from Robin Hood's Cross, and at this level hawthorn bushes and bracken are stunted. Phosphorous also gives plants an early start, hastens maturity and assists in the ripening of the seeds and fruit.

The range of potash deficiency in the soil on the Edge was from 4% near Robin Hood's Cross and Rebellion Knoll to 8% near the stile at the entrance

and near where the willow grows. This result shows that potash is depleted on the heavily wooded lower slopes, which also contain the springs. Potash assists the conversion of sugars and starches, and provides resistance against disease for plants that develop mainly beneath the ground. The lower slopes of the Edge are sheltered, the aspect being westerly. With strong east winds it can be vey cold indeed on the upper slopes.

Regarding the Daleside, it would appear that there is some variation in the levels of pH, the soil generally being alkaline higher up and acid (or approaching neutral) lower down, especially in the little wood. The lowest part of the Daleside is the wooded area, and the undergrowth here is dense - hence more organic matter in the soil. Nitrogen levels are the same everywhere (3%), reflecting the fairly high humus content, but less than those obtained on the Edge. There is, however, considerable variation in the phosphorous levels, which agrees with the point made earlier about no livestock having been kept on the Daleside for the last decade. There is only a 2% phosphorous deficiency in the wood. Nettles flourish in the open spaces in the vicinity, and they are known to be very sensitive to deficiencies in nitrate and phosphorous. Phosphorous levels are satisfactory on the higher, grassy area. The most severe depletion is at the edge of the village, where there is a limestone outcrop and the soil is very scanty. This, however, is one of the areas favoured by the wild thyme, and it also exhibits strong competition between the flora (ox-eye daisies, etc), the encroaching brambles and young ash saplings. Again there is variation in the potash levels, with most depletion in the wood and the upper grassland area. The considerable shelter afforded by the rocks and trees in the Daleside affords protection from the winds and warmth. The disadvantage is the restriction of light and sunshine.

Conditions on the Moor are more clearly defined. The pH is 7.5 everywhere - decidedly alkaline. Indeed, the presence of the Hoveringham Gravels quarry in the neighbourhood would ensure this, if nothing else did. The nitrogen level, with an average 2% deficiency, is more noticeably deficient in Moss Rake and in the little field nearby where the cowslips grow. There is some depletion in the 'Sandhills' area, where the flora is rich and abundant and the wild roses flourish. The phosphorous level is a uniform 2% nearly everywhere, except for the upper part of the 'Sandhills' (4%). The elevation of the Moor and the absence of tree cover has already been noted, as has the scope for light and sunshine.

Conclusion

Geological control of the distribution of vegetation *is* indicated, but in any analysis other factors, such as elevation, degree of shelter or exposure and drainage, should also be considered.

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Deviltry

Adamant A mineral frequently found beneath a corset. Soluble in solicitate of gold.

Deinotherium An extinct pachyderm that flourished when the Pterodactyl was in fashion. The latter was a native of Ireland, its name being pronounced Terry Dactyl or Peter O'Dactyl, as the man pronouncing it may chance to have heard it spoken or seen it printed.

Deluge A notable first experiment in baptism which washed away the sins (and sinners) of the world.

Dictionary A malevolent literary device for cramping the growth of a language and making it hard and inelastic. This dictionary, however, is a most useful work.

GYPSUM IN EAST SUSSEX

Pat Jilks

The Features of Gypsum

Gypsum ($CaSO_4.2H_2O$) and anhydrite ($CaSO_4$) are both forms of calcium sulphate. Pure gypsum, by chemical composition, is 79.1% calcium sulphate, 20.9% water. The rock mined in East Sussex, however, does not contain more than 70% gypsum, having impurities such as clay, limestone, dolomite and silica, as well as iron compounds which lead to colour variations. Its hardness is between 1.5 and 2.0 on the Moh scale - quite soft. The specific gravity of pure gypsum is around 2.3, but the massive gypsum mined in East Sussex, when moisture free, still weighs 8.74/ 9.36kgm^{-3}

Processing Gypsum

When exposed to temperatures above 50°C gypsum dehydrates and loses some of the chemically combined water, forming a new substance - hemihydrate, $2CaSO_4.H_2O$, often called Plaster of Paris. At 50°C a 25mm thick seam of gypsum will be completely converted to hemihydrate in two years, which is obviously far too long for a manufacturing process. In practice temperatures between 128°C and 163°C are used, bringing the time required to heat and convert the gypsum down to between half and one hour. This process is called calcining, during which approximately threequarters of the combined water is driven off as steam. The reduction in the chemical water content is from 20.9% to about 6.2%. If temperatures exceed 163°C the plaster can be overburnt, which will result in excessively long setting times on rehydration.

Rehydration is the reverse of calcination. When the plaster is mixed with water gypsum is reformed and the mixture solidifies. As the plaster sets the chemical reaction gives off heat and causes an expansion in the volume, which makes it ideal for use in moulding and casting.

The Uses of Gypsum

Gypsum has been utilised by man for several centuries, the name gypsum coming from two Greek words meaning 'earth' and 'to cook'. There are three major forms – selenite, alabaster and massive gypsum. Selenite is a clear, crystalline gypsum which can be formed as individual crystals by the decomposition of pyrite. It often occurs in clays, and reaction with any calcium carbonate present can form massive gypsum. Selenite crystals are found at Newhaven, where there are fine examples of twinned crystals, but it is not commercially important in Sussex. In ancient Greece, however, it was used for windows in temples dedicated to the Moon Goddess Selene. (Perhaps such a temple at Newhaven could help to compete with the nearby attractions of Brighton!)

Another type of gypsum is alabaster, which has been used extensively in sculpture and carving. This form is mined in the Midlands but not in Sussex.

The most common form of gypsum, and the subject of this paper, is the massive variety, consisting of an aggregate of crystals which have interferred with the growth of one another. It is used in the main for building materials. Gypsum plaster is one of the oldest building materials in the world. In Egypt, prior to the introduction of lime mortar by the Romans, inferior gypsum mortar was used. In a dry climate this would have been reasonably acceptable, but alternate wetting and drying of the plaster causes failure, so gypsum plaster is best

used indoors in our climate. In the absence of a retarder gypsum plaster sets so quickly that a brick arch can be constructed without a wooden support (the first Jerry building obviously took place around the Nile!). Plaster of Paris, the best known gypsum product, obtained its name from the famous gypsum deposits at Montmartre, near Paris.

The Occurrence of Gypsum in East Sussex

Figure 1 shows the general succession in East Sussex. The gypsum is mainly found in the Purbeck Beds, the lowest 15m of which consist of shales and anhydrite, with four important gypsum seams. Above these the rest of the Purbeck is formed of finely banded shales and mudstones with thin limestones. The beds are exposed in inliers along the crest of the Wealden Anticline between Heathfield and Battle, but the gypsum beds in them are not exposed.

The conditions leading to the deposition of the gypsum came about when the geography of England was drastically changed by orogenic activity at the end of the Portland era. The Portland Basin shrank and ended with a very constricted connection with the sea. The first Purbeck deposits were laid down in hypersaline lagoons, into which the gypsum was precipitated. This lagoon was reflooded from time to time, causing fresh deposits to be laid down. At the time the gypsum was being precipitated England was at nearly 30°N (latitude), about where the Sahara is today.

When evaporitic deposition takes place calcium carbonate is deposited first, then calcium sulphate and finally halite. If the gypsum is able to dry in the sun anhydrite is formed. In Sussex anhydrite is mainly found in the top of the bottom seam, which is also the thickest. Obviously there was a longer time of deposition here, and a longer period before reflooding.

In Sussex gypsum has been worked for over 100 years, the original shafts being near where the Subwealden Borehole was sunk on the axis of the anticlinal Limekiln Wood fold in the Purbeck inlier. Dips within the inlier are variable, and tend to

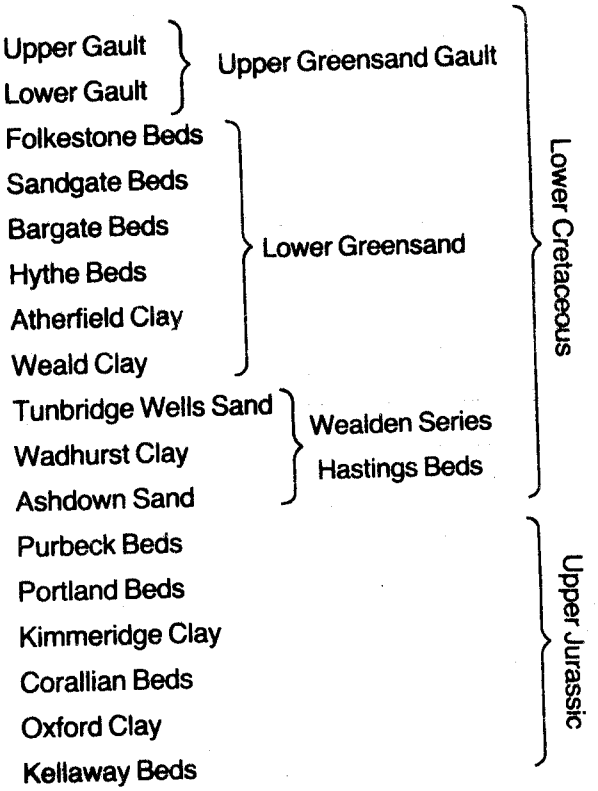

Figure 1

increase outwards from the crest of the plunging anticlinal structure. There are a number of small parallel faults within the deposits, but the strength of the surrounding rocks is such that little or no timber is required for support in the mines. They are relatively dry, any water being drained into old workings on the bottom seam, which now serve as a sump.

British Gypsum Ltd

The company now operating the East Sussex mines was formed from a number of separate companies which were amalgamated by British Plasterboard, mostly in the 1930s. In 1961 two subsidaries of British Plasterboard were formed – Gyproc Ltd and British Plaster and Boards Ltd. One year later the most recent reorganisation amalgamated these two companies under the name British Gypsum Ltd.

The two mines in East Sussex are at Brightling and Mountfield. The output from Brightling is

14 000 tonnes of gypsum per week, and at Mountfield 7000 tonnes of gypsum and 3000 tonnes of limestone are produced each week. Between them these two mines account for approximatley 16% of UK production.

At the Brightling mine there is a good deal of variation in the thickness and quality of the seams in the various parts of the mine. The top, third and bottom seams have been worked, but not the second, owing to the small interval between it and the third seam. Currently the top and bottom seams are being worked. The impurities that occur are mainly calciferous shale and limestone, of cementstone type, in finely laminated bands, or disseminated so that grey calcite encloses nodular masses of pure white gypsum. Anhydrite is occasionally found in the bottom seam, and in the lower parts of the mine specks of bluish-grey anhydrite can sometimes be seen in the third seam. Satin spar occurs as narrow veinlets throughout.

For many years only the top seam was mined, using the longwall method. Now the pillar and stall method has been adopted with the other seams. The 7m square pillars on all worked seams are kept to the same 13m centres, arranged so that they all come under one another. Because of the gypsum left in the pillars recovery is only 75%, but this could be increased at a later date. A 30cm gypsum thickness per acre yields about 2270 tonnes, but the ore is only 70% pure, the rest being mainly carbonates and shale. The rock is blasted out, then loaded with large front-end shovels and sent for primary crushing before going to the surface on conveyor belts. From Brightling to Mountfield the ore is transported by an aerial ropeway going across the countryside for 5km, occasionally glimpsed from the road. It is an unusual and impressive sight to see a convoy of full buckets holding 400kg of ore going one way, with empty ones returning.

At Mountfield there is a processing plant where the ore is treated in a dense media plant, then recrushed and ground into powder. Once in powder form it is calcined by boiling it to remove threequarters of the moisture. The vessels in which this boiling takes place are called 'kettles', and the gypsum is calcined to a temperature of 160°C on a continuous basis. The contents of the kettle then have 10-14% less volume. The material produced is hemihydrate (Plaster of Paris) ready for further processing. The kettle is agitated to prevent overheating and equipped with registering and recording thermometers. Great care is necessary to ensure the uniformity of the product. Contamination by raw gypsum particles can affect the setting time, but the kettle process can be finely controlled.

Gypsum wall board is the principle product at Mountfield, which also makes the hemihydrate plasters 'Thistle' and 'Carlite'. Approximately 6000 tonnes of gypsum/anhydrite a week are sold from the Mountfield mine to the cement industry for use as a retarder in cement. Anhydrous plaster was also produced until about three years ago. In this case all the moisture was driven out using bottle-neck kilns.

Gypsum is used in more ways than is generally realised. As well as the plaster production outlined above and its use as a setting time retarder and controller in Portland cement, it is also used in the smelting of nickel ores, in agriculture to neutralise salt when reclaiming land and to break down the clay fraction in heavy soil to make it more porous and workable, and in the manufacture of insecticides, calcium sulphide, ammonium sulphate, suphuric acid, chalks, crayons and rubber goods, as well as in the filtering and refining of oils. Quite a bit can also be seen in Sussex on rough unmade roads.

Gypsum is obviously a very useful mineral, if less famous than some others. East Sussex therefore produces a commodity which largely passes unnoticed by visitors because it is produced so efficiently and with no despoilation of the countryside.

Acknowledgements

My thanks to Mr W. Wesson of British Gypsum for his help and advise, and to the authors of the IGS *Special Report on the Mineral Resources of Great Britain, Vol. 2 - Gypsum and Anhydrite* and *The Wealden District* in the British Regional Geology Series.

POTASH EXTRACTION IN YORKSHIRE

Gladys Viggars

Introduction

The mining of potash has caused many problems in the North Yorkshire Moors National Park area. Physical resources are the base for industry and the economy: without their exploitation nothing can be gained materially. Raw material only becomes a resource if our technological expertise devises a use for it and enables us to extract it. What is now regarded as a resource may not have been considered so a century ago, and vice versa. These fact are very relevant with regard to resources in and around the North Yorkshire Moors National Park. In this report I have atempted to give a short history of the development and the methods of potash mining, and to discuss the problems associated with the extraction of potash in relation to its situation in a National Park area.

Britain's First Potash Mine

Naturally occurring potash minerals are mined and processed chiefly to provide a source of potassium for compound fertilisers. Current world potash consumption is equivalent to 40 million tonnes per year of muriate of potash (potassium chloride, containing 60% K_2O), the most commonly used form of potash.

The potash deposits in North Yorkshire were discovered in 1939 by the D'Arcy Exploration Company whilst drilling at Aislaby, near Whitby, in search of oil. Extensive exploration for potash in the Whitby area continued from that time, but because of the considerable depth of the main seam, and other uncertain technical factors, commercial extraction was not undertaken. ICI restarted exploration near Staithes, some 16 kilometres northwest of Whitby, in 1964, in an area where geological studies indicated the possibility of workable reserves less deep than those previously discovered. Initial drilling revealed that the potash seam in that area was at least 150 metres shallower than at Whitby. The possibility of extracting the potash by solution techniques was investigated at this stage.

Further exploration around Staithes, and in the area around Robin Hood's Bay and Whitby, has led to the establishment of Britain's first potash mine at Boulby, just outside Staithes. Work started on the site in 1969 and production began in 1973. The deposit is shown by Bryan (1971) to be about 7 metres thick at a depth of 1100 metres. No details of ore-grade at Staithes have been published, but average potassium chloride contents ranging from 21 to 45% have been recorded in five boreholes through the Boulby potash in the Whitby area (Raymond, 1953).

The surface installations at Boulby are located on an 80 acre site and include mine shafts, an ore treatment plant and a rail loading facility. Conventional room and pillar mining techniques are employed to mine up to 10 000 tonnes of ore per day. The ore is broken by explosives and then loaded and hauled by diesel loaders and conveyed to the shafts on belts.

The mined ore has to be crushed and ground before the purified potassium chloride can be separated from the rock salt and other consitiuents of the ore. The separation is accomplished be a froth flotation process. The product is then dewatered in centrifuges, dried in rotary driers and screened. Granular grade output is made by compaction of standard grade material, and the high grade potash for industrial use is produced by crystallisation.

Waste material, which is mainly rock salt or sodium chloride from the flotation process, is discharged 1770 metres offshore through a pipeline laid in a 1770 metre long tunnel out under the

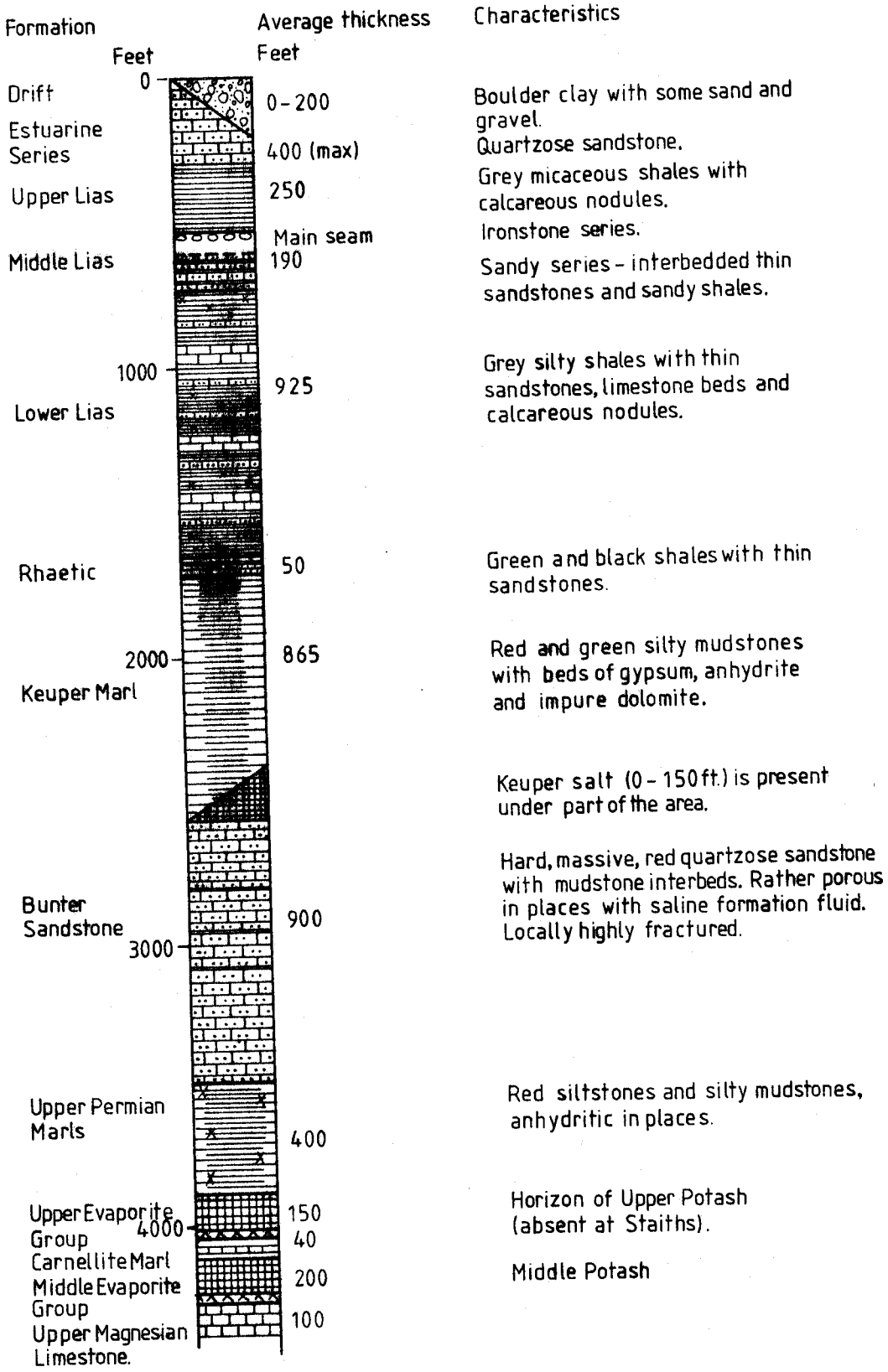

Fig. 1. Succession of geological formations in the Staithes area.

sea bed. This effluent is not expected to disturb marine life or to cause beach contamination, but marine studies to investigate this possibility commenced in 1967, and they will continue to monitor any changes in the marine environment for some time.

About 75% of the total output of the Boulby mine will be despatched by sea to United Kingdom and overseas destinations through a port facility on the south bank of the River Tees. The mine is situated to take advantage of the onshore and offshore deposits of high grade ore, which lie at depths of between 1100 and 1200 metres and which are comparable to the best in the world. Despite all the problems discussed in this paper the mine now appears to be a flourishing concern.

Mining Problems

Before discussing some of the mining problems, a brief reference to the nature and occurence of the potash deposit may be helpful. There are three sites in the National Park area on which potash deposits have been proved at depths between 1100 and 2000 metres. These underlie an area which extends from Saltburn to Whitby. There is little doubt that there is also a substantial offshore extension of the field. The deposits are present in the Fordon Evaporites, the Boulby Halite and the Upper Halite, all of Upper Permian age. They are also known as the Lower, Middle and Upper Potash deposits.

Limited published details of the Boulby Potash (Fleck, 1950; Raymond, 1953; Hemingway, 1958; Smith, 1973) show that it is a highly variable deposit up to 11 metres thick, which appears to be concentrated in lenticular bodies in the Boulby Halite around Staithes and Whitby. Similar limited details of the Upper Potash show that it ranges to 8.5 metres thick. In boreholes near Whitby the Upper Potash is divided into two or three sub-units by beds of halite-rich mudstone (Raymond, 1953). Figure 1 shows the succession of geological formations in the Staithes area and Figure 2 the sequence of evaporite formations associated with the Middle Potash Seam. Extraction is initially only in this seam.

The initial problem to arise was the choice of method of extraction - by conventional underground mining or by solution? Two companies, Cleveland Potash Ltd and Yorkshire Potash Ltd, decided on conventional mining techniques, whilst a third company, Whitby Potash Ltd, chose solution techniques. At the present time only Cleveland Potash is in operation and the mining techniques and production details are as detailed above.

The decision to use conventional mining techniques was based on the following factors:

1 both the companies wishing to mine the potash intended to exploit the offshore reserves, which they believed could only be reached by conventional mining techniques
2 access to the Upper Potash Seam could, if necessary, be gained from the workings in the Middle Potash Seam
3 conventional mining eased the process of selective mining
4 the Middle Potash Seam in their areas was not thick enough for economic solution mining
5 conventional mining would, in their view, reduce the risk of subsidence damage.

Whitby Potash's proposed site had no offshore reserves and the company had available to them considerable knowledge and experience of solution mining gained in Canada.

Problems of roof support and subsidence involved specialist advisers. An extensive laboratory programme was carried out, the results of which, though directed to solving the Yorkshire problems, would also contribute to a pool of knowledge about the general theory of evaporite rock behaviour.

Because there is a lack if experience of the extraction of potash at the depths proposed, the companies using conventional mining techniques agreed that a programme of underground and surface observations would be undertaken when their respective mines came into production. This would enable modifications to be made in the underground mining layout in the light of experience.

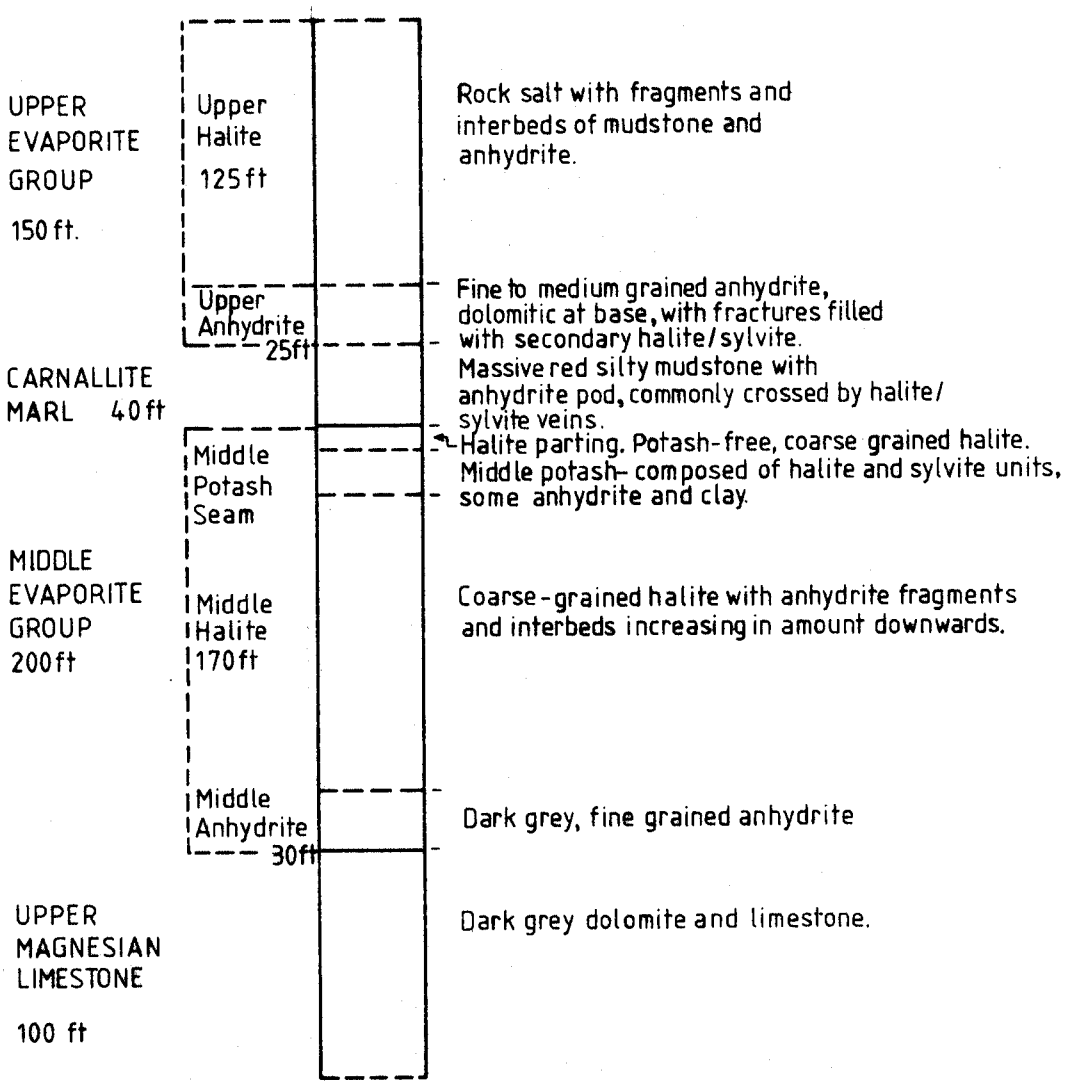

Fig. 2. Sequence of evaporite formations associated with the middle Potash seam.

Conventional mining sooner or later causes partial, and even total, convergence between the roof, floor and sides of the excavations, resulting in subsidence of the overlying strata, the effects of which may or may not reach the surface. The extent and amount of subsidence depends on the following factors: method of working; extent of workings; thickness of rock or mineral extracted; percentage extraction; depths of workings; nature of overlying strata; the presence of old workings in overlying seams; and the presence of faults or other geological phenomena. The last two factors are of great importance in this area. Old ironstone workings are present over part of the field, the land along the coast is of an unstable nature and the beds in the overlying strata are water-bearing. Because of these problems the method of working the potash was specifically designed so that the pillars of potash left behind could not only take the weight of overlying strata and control its movement but would also prevent undue fracturing of the immediate beds.

With solution mining it is difficult to estimate the subsidence risk. Experience of the application of solution mining to the winning of potash in the United Kingdom is very limited. The art of efficient and safe solution mining lies mainly in the effectiveness of the techniques used for:

1 controlling the rate and direction of solution and, accordingly, the size and shape of the cavities
2 recording the position and dimension of the cavities both initially and relative to one another
3 preventing the collapse of cavities by maintaining pressure within them, thus eliminating the risk of surface subsidence.

Compared to the problem of obtaining planning permission for exploration and exploitation of potash the geological problems seem small. The second part of this report deals with the National Park Authority and the problems of extracting potash in a National Park.

The Work of the National Park Authority

The principle objects of designating an area as a National Park are:

1 the preservation and enhancement of the natural beauty of the area
2 the promotion of enjoyment of the area by the public.

The county council in this area set up a separate planning committee to look after the interests of the Park. For the first of their principal functions the committee rely chiefly on the normal planning powers, which the county council, as local planning authority, had been exercising before the area became a National Park. In administering control over new development the general policy is to limit this to what is essential to the normal life of the area, to prevent unneccesary and incongruous development and to ensure that what buildings are erected are suitably placed and in keeping with the existing settlements. Isolated buidings in the open countryside are avoided as far as possible.

Surface mineral workings are developments over which the planning authority exercise close control, and a number occur in the North Yorkshire Moors National Park. They produce obvious scars on the landscape but, although in some places their prohibition may be justified, they supply an essential need and provide employment, and as such are part of the economic life of the area. The policy is, therefore, not so much to seek to prevent them as to permit them subject to stringent conditions requiring orderly working and restoration after working has ceased.

The committee's policy at the moment is being considered as part of the preparation of the National Park Plan. The question of mineral exploitation is also being considered in the North Yorkshire County Structure Plan, which will not be available until 1978. To quote from this year's (1976) National Park Handbook, "in recent years exploration for deposits of potash and natural petroleum has been taking place, and in the next few years *it is likely that these valuable minerals will be extracted* from locations inside the National Park. The Committee accept that it is in the national interest that these resources should be exploited, but the Committee will seek to ensure that only *essential* development is carried out within the Park and that all installations and structures are sympathetically designed and sited" (my italics).

The same handbook states that borings of an area around Ralph Cross gave proof of usable gas deposits but, on strong representations against it being worked there, it was put at the time in the category of 'possible reserves'. It is now understood that the exploitation of this natural gas has proved to be a commercial proposition.

Planning Permission and Potash Extraction

In previous times, for example when jet, alum and ironstone were mined, there seems to have been little or no planning problems, as long as the areas to be mined were on poor agricultural land. In 1947 the Town and Country Planning Act came into being. Under this system, which operated until the reforming legislation of 1968, development plans had to be prepared by each local planning authority and reviewed every five years. The 1947 Act defined a 'development plan' as a "plan indicating the manner in which the local planning authoriy proposes that land in their area should be used". These plans were to cover a period of about twenty years. They included numerous maps, written statements and analyses which described and defined the major projects in the plan. This massive framework of planning legislation was consolidated in the Town and Country Planning Act of 1962. In 1968 a new Act was passed which made various changes. A new form of plan had to be made consisting of three parts:

1 a structure plan submitted for ministerial approval. This consisted of a written statement of policy, accompanied by a diagrammatic structure map showing the basic pattern of development
2 action area plans
3 other local plans to meet local needs.

The 1968 Act enabled local planning authorities to delegate responsibility for certain decisions to their planning officers, and required the authority not only to publish its proposals but also to consult with local people. The designation of areas of countryside as National Parks, as defined by the National Parks and Access to the Countryside Act 1949, also brought new rules and regulations.

1970 was European Conservation Year and this has proved to have been of great influence in recent development. Attention was focussed on 'pollution' and the 'environment', and a new meaning was given to these words. The television medium brought to millions a new awareness of the potential of the countryside and the ability of industry to destroy it. In the North Yorkshire Moors area this has led the problems surrounding the extraction of potash to cause great controversy and to create feelings of bitterness.

As it was considered that the exploitation of the potash deposits raised issues of national importance, a directive was made as far back as 1951 that all applications to exploit potash deposits should be referred to a Minister of State for decision. In 1968 the three applications for planning permission for the winning of potash deposits in north-east Yorkshire were formally presented. The Minister decided to hold a public inquiry into each application. He appointed one of his inspectors to conduct all three inquiries, assisted on each occasion by two assessors, one mining and one geological. The matters thought relevant to a consideration of the application were:

1 the nature and occurence of the deposits and the overlying strata
2 the expected output and its contribution to national and regional economics and to the balance of payments
3 the proposed method and scale of mining and their implications, and the expected life of the mine
4 the risk of subsidence and possible effects on the surface
5 the nature and quantity of waste material, its method of disposal and the expected effects
6 possible effects of operations in relation to proposals for potash extractions by other companies in neighbouring areas
7 the siting of mineheads, processing, storage and despatch areas, and the nature and size of buildings and plant, having regard to the amenities of the National Park as well as other economic and amenity factors involved
8 the availability of suitable labour and housing.

From this list it can be seen that a great deal of preliminary work and investigation must be done,

and the whole process from start to finish must be thought out. It is not just a matter of saying 'there's some potash down there, let's get it out', which is what some people think is happening. A public inquiry gives everybody the opportunity to see what is planned and how it will affect them personally.

The importance of the mineral extraction industries to the economy of this country and to our standard of living is immense, yet this obvious fact is not always clearly understood by the general public, or even, sometimes, by those in authority. The general public need to be convinced that those who develop mineral resources are not reckless profiteers, and the companies concerned must realise that they have an obligation not only to justify their schemes in financial terms but also to demonstrate a willingness to co-operate as far as possible with any legitimate interest likely to be adversely affected, even if this requires more costly and complex solutions. The community will demand more and more that its total needs are taken into account, and a public inquiry gives an opportunity for both the company and the community to get together and sort out the problems.

After the public inquiries, planning permission for the mines was granted by the Secretary for State for the Environment in 1968. Cleveland Potash now has a mine in production, as discussed above. This year (1976) the controversy has begun again. The North York Moors National Park Committee had decided by one vote to refuse an extension of the outline planning permission for the other two mines, which had been granted in 1971. Whitby Potash wished to build a refinery site just outside the Park boundaries, while the rest of the 12 000 acres involved are within the Park. There are plans for structures from 80 to 130 feet high, and a 260 feet stack for waste gases. Rail transport would be needed to convey 450 000 tonnes of potash per year. When the original permission was given world potash prices fell and the whole plan was shelved. Yorkshire Potash's plan involved the use of 15000 acres between Whitby and Robin Hood's Bay, near the coastal section of a long distance walk, the Cleveland Way. Rail transport would again have been used to transport one million tonnes of potash per year. Again the fall in potash prices meant that the planning permission was not taken up.

Both companies appear to have no immediate plans to build their mines; it seems to be just a matter of keeping the option open ready for when the deposits become commercially viable. More details may, however, come to light during the next few months as the controversy rages. The North Yorkshire County Council told the Moors planning committee to think again, because of the unemployment situation in the Whitby area. After heated discussions the committee agreed to tell the mining companies that they would look at their plans again. Now, although after the public inquiries held previously one would assume that everything was sorted out, a Whitby Potash Action Group has been formed to fight the committee's decision. The Action Group has asked the Environment Secretary to intervene in the controversy and to set up an independant research team to carry out a comprehensive investigation into the needs of the area in relation to the quality of life and the standard of living of its people. Surely this should have been covered by the first inquiries, or set up as a result of them, not left to now. The development of the two potash mines could be worth £70 million annually to Britain's balance of payments.

To date the controversy still rages while every angle is explored. The people of Whitby will have to decide what is most important to them; jobs and better amenities or the scenery which in many respects is spoilt by another resource, the tourist industry. Surely, in the interests of everyone and in line with National Park policy, a compromise can be reached so that both the industry and the scenery are kept.

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Letters

Have OU teaching materials helped you in the classroom?

I am interested in contacting OU teacher-students for two purposes. Firstly, I am currently undertaking what might best be called a 'feasibility study' concerning the possibility of mounting OU based in-service courses for teachers. Secondly, I believe there may be ways of resurrecting the Association of Teachers of Geology's ill-fated curriculum development project 'Geology across the Secondary School Curriculum' (see *Geology Teaching*, 2/4, pp162-3 and 3/1, pp2-3) by capitalising on existing and planned OU material.

In-service Courses

On the evidence of many individual conversations with students (rather than formal surveys) it seems that the OU science courses have acted, by accident rather than design, as in-service training aids for teachers. OU teacher-students have had their scientific horizons broadened, and some primary teachers have been encouraged to include science (not labelled as such as far as the students are concerned) in their curricula. I have the impression that it seems likely that curriculum design and assessment strategies have been influenced too. Indeed, during the first year of presentation of the Science Foundation Course, back in 1971, the Science Faculty had many enquiries from teachers concerning the possibility of mounting an in-service course specifically designed for their needs.

Early in 1972 the faculty held a conference involving 33 teachers, with the purpose of thrashing out a possible in-service course. Regrettably the burden of trying to complete an idea born out of staff and students' enthusiasm during the heady days of the OU's first few years proved too much. The idea, however, was never completely forgotten, and the faculty is now committed to investigating how it can contribute to teacher in-service training, having given time to a number of staff to work out proposals after consultations with a variety of people and organisations. As well as talking to local authority advisors, the science inspectorate, the ATG and the Association for Science Education, I am keen to hear the views and experience of any teachers (including our teacher-students) who have used and/or have been influenced by our science courses. We may well be able to build on your experience when preparing the course material.

Our thinking at the moment errs towards two courses, one for primary teachers and the other for secondary teachers. Whilst our existing courses may have helped the former group there is clearly a need for a course that will conquer the fear of science that many primary teachers appear to have - only the hardiest of them will have done OU science courses. Nonetheless, the experience of primary school teachers who have taken science courses, or been stimulated by them to introduce science topics in their classrooms, could prove invaluable to a team designing an OU primary science in-service course.

As to the course for secondary teachers, the target audience is less easy to identify. At present there is much talk of tackling the shortage of physics teachers by the provision of conversion kits for teachers of other science subjects. Maybe existing and planned science, maths and technology OU courses can provide a fair bit of 'conversion', at least in terms of academic content, but help of a more pragmatic kind - how to do it in the classroom - is also needed. The problem of conversion is that it can probably only work on good teachers, and good teachers of say, biology, will already be making their way up the subject career ladder. So perhaps any secondary level course the OU mounts should aim more at *broadening* the outlook and approaches of science teachers by encouraging them to study (through the existing undergraduate programme) science disciplines they might have missed during their initial training, and by providing a pragmatic in-service course that would be directly useful to their everyday work in the classroom. What an opportunity there is here for geology!

We are convinced that any specially prepared science in-service courses should be strongly school-focussed in their approach, providing ideas, advice and information that will have direct application in the classroom. Moreover, we believe that any science in-service training courses that are produced should be designed so that teachers may study them at various levels of commitment, ranging from a few hours of study of one or two sections of the course, through the completion of a 16 week course, to a combination of in-service and existing undergraduate courses into a degree course. Discussions we have had so far with teachers and lea advisors suggest the course should allow those taking it a fair degree of choice, enabling them to study 'packages' that will fill gaps in their initial training. Equally important will be an element of individual work, in which course content is applied in the classroom situation.

At this stage I don't want to elaborate further on the nature of either the primary or secondary courses, preferring to wait for comments from practicing teachers on what we should try to produce. **So please write soon!**

The Missing Science

My second plea for comments from our teacher-students arises from a long interest I have had in geology teaching at school level. Several years ago I was a member of the ATG team that tried to get funds to mount a development project entitled 'Geology across the Secondary School Curriculum'. We didn't pull it off but, despite the current financial gloom, the Association is still trying to foster the teaching of geology at both primary and secondary levels. This is not to advocate the insertion of another science subject into an already crowded curriculum - having to choose two, or worse still one, from physics, chemistry and biology gives many pupils an incomplete view of science. The Association has stated on many occasions that in these resource conscious times the geological sciences have a place in both a broad introduction to science from the primary level onwards *and* as an element in the study of biology, chemistry and physics.

OU earth sciences courses *do* provide such experiences, and their popularity is probably due to the fact that schools do not include such approaches in the courses, so that our students are now making up for denied opportunities. From time to time I have met OU science teacher-students who, because they have taken earth science courses, have introduced the subject into their schools, either as a separate subject or as a component of other science courses. In 1977 I held a small workshop meeting at which teachers who were not OU students discussed how they had used our texts, TV programmes and teaching methods in their own classrooms (see *Geology Teaching*, 2/2, p66). The impression gained at the time was that there is a large, untapped source of materials and ideas to be developed by teachers using OU course materials as a starting point. And many of these 'starting points' are already distributed to everyone free - as TV programmes! So I would like to get in touch with more teachers with such experience with a view to developing geological materials and ideas that could be used by teachers of science at the primary and secondary levels.

Contacts with primary teachers would be especially valuable, as the joint ATG/ASE working group set up to foster the development of geological topics for use in science courses has been asked by the 'Learning through Science' project (the follow-up to 'Science 5-13') to suggest topics to include in a theme tentatively entitled 'Beneath our Feet'. The project will subject these topics to trials, and the materials will eventually be published along with the other project materials.

If you have any comments concerning the kind of science in-service training for teachers the OU should provide, and on the contribution the geological sciences can make to science teaching in schools, please write to Chris Wilson at the Department of Earth Sciences, Open University, Walton Hall, Milton Keynes MK7 6AA.

Geological Site Recording

A national scheme for geological site documentation has been set up by the Geological Curators Group. It uses Record Centres, mostly connected with County Museums, to cover most of England, except for parts of the Midlands, with Wales and Scotland being rather thinly served so far. The scheme has only been in existence since 1977, but it is growing wherever funds are available.

The aim of the scheme is to record all geological sites, the information required being under the headings: locality name; grid reference; parish, district and county; field recorder's name, and date of visit; type of locality (quarry, road cutting, etc); main extraction method (if quarry); condition of locality on date of visit; dimensions of site; non-geological interests (nature reserve, archaeology); general description of locality; stratigraphy; petrology; mineralogy; palaeontology; structure; relationships; geomorphology; palaeoenvironment; general history of locality; planning authority; conservation status; management body; owner; tenant; access and restrictions; facilities for visitors; present use; potential use (general and educational); threats to locality; visitors; maps; plans; bibliography; collections.

These records can then be made available to students and field trip leaders. It is particularly important that ownership, and any restrictions on access, be recorded, since the goodwill of the owner is vital for continued study. Although the Geological Curators Group work in co-operation with the Nature Conservancy Council the aim of their two surveys is slightly different. The NCC wish to identify and designate Sites of Special Scientific Interest, in order that they can protect sites covering the stratigraphic column in the UK. Protection from over-use is as important as protection against destruction by development, or sea defences. If protection is to be effective the number of sites must be kept to a minimum. The Record Centres aim to record everything and, with the help of experienced teachers of geology, to evaluate their educational potential. In the long run this should help to relieve the pressure on SSSIs and over-used sections. Leicester Record Centre have begun issuing leaflets on particular sites with this in mind.

OUGS members could do useful fieldwork in connection with the scheme - indeed some individuals and groups are already participating. I have been working voluntarily in the Dorset Record Centre for the past 18 months (there has been no funding since the end of 1978) and would be most grateful for assistance. We have a reasonable base of records, including most of the SSSIs and well-known sites, but the work done by the first two full-time geologists was almost exclusively literature searches. I need to know the present condition of sites, and the ownership. If you are visiting Dorset please drop me a note on the sites you have seen, and any information you have gleaned. Also, a copy of any detailed fieldwork would be most valuable. Those who are interested in participating in their local scheme should get in touch with their County Museum or, failing that, Leicester Museum, where the scheme started.

Mrs. Jo Thomas
Dorset Environmental Record Centre
Dorset County Museum
Dorchester, Dorset

Geology and the Bible

The Summer 1980 editorial asks for critical thought, so here are some observations on John Saunderson's interesting article, 'Geology and the Bible'.

I had always thought that the Old Testament was Jewish rather than Christian, but either way I think it is unreasonable to say that the sacred writings of other religions are seldom regarded as being worthy of scientific consideration. For example, I thought it was fairly well established that the 6-day creation story

came from the Babylonian *Enuma Elish*, which was itself based on a Sumerian story from about 3000BC. The Israelites learnt about it during their stay in Babylon in the 6th century BC, and wrote it down as part of the Pentateuch when they got home again. The *Enuma Elish* (dating from about 1500BC) talks about the creation of the Earth from a watery abyss, and the second verse of Genesis talks about the 'face of the deep' and the 'face of the waters'.

As for the OU geology courses not mentioning 'special creation', note that S23 assumes prior study of the science foundation course, so for details of special creation see S100 unit 19, page 9, and unit 26, page 9.

I agree with John that evolution is an emotive subject (a good example being Christopher Booker's emotive article about Darwin and evolution in the Spectator last year - he ought to have studied S100 first). Unfortunately there are many theories of evolution, of which Darwin's is probably the least well understood. The best known theory of evolution, and the easiest to understand, is the one described as a number of special cases by Kipling in the *Just So Stories*. These tend to be generalised by critics and, as the principles involved are vaguely similar to Lamarck's, the resulting 'theory of evolution' looks respectable, but is indeed difficult to treat in a rational scientific or theological manner.

To comment on some of John's observations (John's headings in brackets):

1 (Biblical Problems) 'Day' is defined in Genesis verse 5. It is light. The sun and seasons were not set up until day 4, so presumably a temporary inspection lamp was mounted on the plane of the equator during the first three days.
2 (Geological Problems) John is quoting S23 out of context. The 'evidence that is not convincing' is whether Cambrian life is less complex than recent life. Nothing more!
3 (Creationist Hypothesis, Phase 1) If God had asked for my advice, I would have counselled against the installation of shell fossils in pre-Carboniferous limestone. Such things are liable to mislead future investigators looking for the truth, and are thus counterproductive.
4 (Box on right of page 16) a) 'Universe and life not formed by chance' - why not? John says 'probability is infinite', but I think it is usually quantised. One of Christopher Booker's arguments against evolution was 'how could anything evolve or arise from completely random events?' Casinos and insurance companies arose and exist as the result of a very large number of random events. Their profits, which are fairly predictable, are a further consequence of such random events. Scaling the same argument up several orders of magnitude, why should the Earth we live on not be one of a vast number of the consequences of individually random events? Because it is just right for us, and hence is too much of a coincidence? If it were not just right for us we would not be here - we would be somewhere else on a 'consequence' that was just right for us. And how would we know?
b) 'Man is unique' - is that so? Neanderthals may well have regarded themselves as unique, and maybe Homo Erectus as well. They are both extinct now, but I think Neanderthal man lived at the same time as early Homo Sapiens. (If Noah's flood took place in the early Cenozoic all hominoids - Australopithecus, Homo Erectus, etc - must have lived contemporaneously with Noah's decendents.) Man may be unique at the moment, but I doubt if this was always so.
c) 'Much dating evidence indicates a recent age for the universe' - can John supply a reference?

Finally, how short a time is short?

Colin Davis

Colin has quite rightly asked me to point out that his letter was dropped from the earlier issue due to lack of space, but was written before my comments on scientific argument. Despite what I said about the need for objectivity last time, I still intend to publish 'non-scientific' letters if they are likely to be of interest to members, providing I have the room. Properly argued cases will, however, always receive priority.

Branch Report

A Tour of Irish Dykes

Last September Norman Butcher, the OU Science Staff Tutor in Scotland, arranged a field trip to Northern Ireland for geology students from the Scottish area. Ian Meighan of Queens University, Belfast, kindly agreed to lead the trip, and met us off the ferry at Larne with the mini-buses.

We headed south from Larne through County Down towards Belfast, passing many perfect drumlins on the way through this textbook example of a drumlin swarm. We also noted some basalt flows which contained red horizons, called boles, of weathered, lateritic, basalt formed on what was originally the surface of the flow. Potassium-argon dating of these flows shows they are around 60 million years old, making them contemporaneous with the Mull basalts.

Our first stop was at Bellshaws Quarry. This ceased working 100 years ago and is now a nature reserve. The Triassic/Cretaceous/Tertiary/Quatenary sequence here shows Cretaceous chalk overstepping Triassic, with a pebbly, glauconitic chalk marking the transition. The massive chalk above includes flintbands, and is capped by a Tertiary Lower Basalt. A layer of Boulder Clay covers the basalt. The Chalk and the Lower Basalt, but not the Boulder Clay, are cut by a basalt dyke. The Triassic is not noticeably affected by this as it has been overstepped before the dyke is reached, but another slickensided fault in the Chalk above the Triassic does not apparently extend into the Triassic. The Lower Basalt includes some zeolites which are probably formed of Thompsonite.

We then proceeded to the aptly named Silent Valley, a reservoir site in the Mourne Mountains. It has been laid out as parkland, but the shrubberies are now closed to the public due to the troubles in the province. The fuschias and deep blue hydrangeas growing here indicate an iron-rich soil and a mild climate. The Mourne Mountains are formed principally of five types of granite, noted on the geological surveys by the numbers G1, G2, G3, C4 and C5. In Silent Valley we saw the drusy G3 granite, which has aplite veins running through it. This sequence provides a good example of a granite roof, and it is also cut by a later basic dyke.

The next stop was at Glassdrumman Bay, where we saw the intrusion of granite and basalt cone sheets into Silurian rocks, which were dipping steeply southeastwards. The doming of the cone sheets was deduced to be caused by the intrusion of the Mourne granites.

We spent the night at Queen's field centre at Dundrum Bay, where it rained all night! The next morning it was still raining but we set off gamely for the Giants Causeway. Our first stop was at Tardree, where we saw an excellent outcrop of porphrytic rhyolite containing sanidine and oligoclase feldspars and black quartz crystals set in a fine groundmass. The sanidine was identified by its glassy nature. This 58 million year old rock is classed as extrusive, but is probably intrusive. It shows signs of columnar jointing and is dome shaped in outcrop. If this rock had weathered under tropical conditions it would have produced an ideal bauxite.

On our way to Portrush (of golf course fame!) we passed the hill known as Slemish, a large, eroded dolerite plug. At Portrush we saw a gabbro sill intruded into Jurassic sediments, producing a hornfels containing ammonites! As this is an SSSI hammering was not allowed.

Between Portrush and the Giants Causeway we passed the Bushmills distillery – alas without stopping! The laterites in the basalts of the Giants Causeway indicate that there may have been a long time between flows, the amount of weathering needed to produce boles being quite considerable. Some of it may, however, be due to volcanic ash blown into the deposits from elsewhere. There are no zeolites in evidence but I found some vesicular basalt containing geothtite.

As time was now pressing (to catch the ferry) we went at a cracking pace to Fair Head, to see a coarse-grained dolerite sill intruded into the Carboniferous rocks, and then on to Murlough Bay to see the Dalradian schist outcrop. This foliated, micaceous schist is one of the oldest rocks in Ireland, but it is overlain by Carboniferous, and in places by Triassic and Cretaceous, rocks, not to mention the ubiquitous Boulder Clay. The Carboniferous Conglomerate Sandstone was cut by yet another dyke! On our way to Larne we even saw some cormorants drying their wings on offshore rocks. Before boarding the ferry home we expressed our thanks to Ian for his excellent leadership.

Arthur Forsey

Devil's Dictionary

Faith Belief without evidence in what is told by one who speaks without knowledge, of things without parallel.

Gravitation The tendency of all bodies to approach one another with a strength proportioned to the quantity of matter they contain – the quanitiy of matter they contain being ascertained by the strength of their tendency to approach one another. This is a lovely and edifying illustration of how science, having made A the proof of B, makes B the proof of A.

Lead A heavy blue-gray metal much used in giving stability to light lovers – particularly those who love not wisely but other men's wives. Lead is also of great service as a counterpoise to an arguement of such weight that it turns the scale of debate the wrong way. An interesting fact in the chemistry of international controversy is that at the point of contact of two patriotisms lead is precipitated in great quantities.

CONSTITUTION OF THE OPEN UNIVERSITY GEOLOGICAL SOCIETY

1 NAME

1.1 The Organisation shall be called the Open University Geological Society (and may be referred to as the O.U.G.S.).

2 AIMS

2.1 To promote interest in Geology, especially among members of the Open University.

2.2 To sponsor the formation of Branches.

2.3 To support the Branches in their activities.

2.4 To arrange an Annual Conference.

2.5 To establish and maintain good relations with organisations having common interests.

3 MEMBERSHIP

3.1 Membership shall be open to all members and one-time members of the Open University.

3.2 Associate Membership shall be open to any other persons.

3.3 Family membership shall be available for any other adult, named persons of a member's family residing at the same address.

3 SUBSCRIPTION AND FINANCE

4.1 The Society Financial Year shall be from 1st October to 30th September the next year.

4.2 Members, Family Members and Associate Members shall pay an Annual Subscription, to become due on the first day of January each year.

4.3 The Annual Subscription shall be £2.50, or an amount to be decided at the Annual General Meeting, and shall become due in January each year.

4.4 The Annual Subscription shall be paid to the Hon. Treasurer.

4.5 Any Member, Family Member or Associate Member whose subscription is not paid by the last day of March for that year shall cease to be a Member.

4.6 Each Officer and Branch Organiser shall keep a record of accounts.

4.7 The Hon. Treasurer shall prepare a statement of the overall accounts and an audited version shall be presented at the A.G.M.

4.8 The O.U.G.S. shall have the power to raise funds from other sources.

5 GOVERNMENT OF THE SOCIETY

5.1 Government of the O.U.G.S. shall be carried on by:

The President and the following Officers:
- Chairman
- Hon. Secretary
- Hon. Treasurer
- Hon. Conference Secretary
- Hon. Publicity Secretary
- Hon. Editor
- Hon. Membership Secretary

5.2 The Officers shall be elected from among the Members of the O.U.G.S., by consenting nomination of two Members and by majority vote at the A.G.M., to serve for one year and be eligible for re-election, except for the Hon. Conference Secretary, who shall be appointed by the National Committee at an appropriate time.

5.3 There shall be a National Committee consisting of all Officers together with Branch Organisers.

5.4 The Officers shall act individually or collectively as an Executive to deal with routine matters within the terms of reference given by the Society and in accordance with the Aims of the Society.

5.5 When a vacancy occurs by reason of resignation, disqualification or death of an Officer, a replacement shall be appointed by the Executive to fill the vacancy until the next Annual General Meeting, at which the replacement shall retire and be eligible for re-election.

5.6 The Society through its executive shall be empowered in exceptional cases to offer a position of Hon. Vice President to such person or persons who have performed outstanding service to the Society.

6 PROCEDURE AND BUSINESS

6.1 There shall be an Annual General Meeting in November each year.

6.2 The Hon. Secretary shall give eight weeks notice in writing to all Members of the date, time and venue of the meeting.

6.3 Officers, National Committee, Branches or Members shall give the Hon. Secretary at least six weeks notice in writing of any motion, proposal or matter they wish to have placed on the Agenda for the A.G.M.

6.4 The Hon. Secretary shall send out the Agenda for the A.G.M. at least two weeks before the meeting to all Officers, Branch Organisers, Members and Associate Members. Amendments to motions may be submitted before or at the meeting.

6.5 All Officers shall retire at the A.G.M., but be eligible for re-election (see 5.1 and 5.2).

6.6 A Member may not hold the same Office for more than 5 years consecutively.

6.7 The Auditor shall be appointed at the A.G.M. for the next year.

6.8 A Special General Meeting may be called at the request of the Executive or three Branches.

6.9 Within two weeks of receipt of the notice in writing requesting a Special General Meeting, the Hon. Secretary shall give not less than three and not more than five weeks notice of the agenda, in writing, to Members and Associate Members, giving the date, time and venue.

6.10 The National Committee shall meet at least twice each year, namely during the Conference and immediately before the A.G.M.

6.11 The National Committee shall be empowered to form Special Committees whose objectives and reporting dates shall be fixed. All Members shall be informed of such formations within thirty days.

6.12 Minutes shall be taken of all meetings and copies circulated to the National Committee Members. A resume of important points arising from the A.G.M. or a Special General Meeting shall be published in the first Journal thereafter.

6.13 The Constitution may only be amended at the Society A.G.M. or at a Special General Meeting called for the purpose.

6.14 A Branch Constitution may only be amended at the Society A.G.M. or at a Special General Meeting called for the purpose.

6.15 General Meetings shall be conducted according to Standing Orders for General Meetings (see Appendix 1).

6.16 Associate and Family Members may speak on Motions but may niether become Officers or Branch Organisers, nor vote.

6.17 All voting decisions shall be by a simple majority of those entitled, present and voting.

6.18 Notices of Motion may only be made by fully paid Members, Branches, the National Committee or the Executive.

6.19 The Chairman or other Presiding Officer shall not have a vote except in the event of a tie, when he shall have the casting vote.

6.20 A Quorum of fifteen shall be required at the Annual General Meeting, two of whom shall not be National Committee Members.

6.21 A Quorum of twenty-five shall be required at a Special General Meeting.

6.22 A Quorum of five shall be required at a National Committee Meeting.

7 LIMITATIONS

7.1 The name of the Society may not be used without the permission of the Executive or Branch Officers.

7.2 The Society cannot accept liability for costs for any damage, fire, theft, legal fees, injury, etc.

7.3 The Society shall have the right to suspend or expel any Officer, Committee Member, Member, Family Member or Associate Member acting against the Aims of the Society, after full consideration of the case at a Special General Meeting called for the purpose. The Member shall have the right to present his case either orally and/or in writing and be represented by any other person of his choice.

7.4 The person so treated shall have the right to appeal to the Society at the A.G.M. immediately following.

8 INTERPRETATION

8.1 The O.U.G.S. shall be the sole interpreter of their Constitution.

8.2 Any matter not provided for in the Constitution shall be dealt with by the Officers acting individually or collectively as an Executive pending endorsement by the O.U.G.S. Annual General Meeting.

23rd April 1976
As amended on 10.4.76 and 1.12.79

Deviltry

Molecule The ultimate, indivisible unit of matter. It is distinguished from the corpuscle, also the ultimate, indivisible unit of matter, by a closer resemblence to the atom, also the ultimate, indivisible unit of matter. Three great scientific theories of the structure of the universe are the molecular, the corpuscular and the atomic. A fourth affirms, with Haeckel, the condensation or precipitation of matter from ether – whose existence is proved by the condensation or precipitation. The present trend of scientific thought is towards the theory of ions. The ion differs from the molecule, the corpuscle and the atom in that it is an ion. A fifth theory is held by idiots, but it is doubtful if they know any more about the matter than the others.

Monad The ultimate, indivisible unit of matter. (See *Molecule*.) According to Leibnitz, as nearly as he seems willing to be understood, the monad is a body without bulk, and mind without manifestation – Leibnitz knows him by the innate power of considering. He has founded upon him a theory of the universe, which the creature bears without resentment, for the monad is a gentleman. Small as he is, the monad contains all the powers and possibilities needful in his evolution into a German philosopher of the first class – altogether a very capable little fellow. He is not to be confounded with the microbe, or bacillus; by its inability to discern him, a good microscope shows him to be an entirely distinct species.

Observatory A place where astronomers conjecture away the guesses of their predecessors.

Past That part of Eternity with some small fraction of which we have a slight and regrettable acquaintance. A moving line called the Present parts it from an imaginary period known as the Future. These two grand divisions of Eternity, of which one is continually effacing the other, are entirely unlike. The one is dark with sorrow and disappointment, the other bright with prosperity and joy. The Past is the region of sobs, the Future is the realm of song. In one crouches Memory, clad in sackcloth and ashes, mumbling penitential prayer; in the sunshine of the other Hope flies with a free wing, beckoning to temples of success and bowers of ease. Yet the Past is the Future of yesterday, the Future is the Past of to-morrow. They are one – the knowledge and the dream.

Pre-Adamite One of an experimental and apparently unsatisfactory race that ante-dated the Creation and lived under conditions not easily conceived. Melsius believed them to have inhabited "the Void" and to have been something intermediate between fishes and birds. Little is known of them beyond the fact that they supplied Cain with a wife and theologians with a controversy.

Radium A mineral that gives off heat and stimulates the organ that a scientist is a fool with.

FOSSILS, EVOLUTION AND ANCIENT ENVIRONMENTS

3rd - 5th July 1981

KEBLE COLLEGE, OXFORD

Speakers include:	Speaking on:
Dr. Denis Bates (University of Wales)	Some unusual graptolites, their structure and evolution
Prof. W. Chaloner (Bedford College)	The land migration of plants
Dr. Simon Conway-Morris (OU)	Burgess Shale
Dr. G. R. Coope (Birmingham)	Beetles as envrionmental indicators
Dr. J. N. Hancock (Kings College)	Late Cretaceous extinctions
Dr. Denis Jackson (OU)	Summation
Dr. Hugh Jenkyns (Oxford)	Marine transgressions
Dr. Tim Palmer (Oxford)	The evolution of fossil communities
Dr. R. Savage (Bristol)	Continental drift and the history of mammals
Dr. Colin Scrutton (Newcastle)	Periodicity of the Earth's rotation, the evidence from fossils
Prof. D. Shearman (Imperial College)	Ancient evaporitic environments
Dr. Peter Skelton (OU)	The evolution of reefs

For further details contact Ivan Foster, OUGS Conference Secretary